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Musculista senhousia (Benson in Cantor, 1842) (Bivalvia: Mytilidae) in the coastal waters of the Adriatic Sea (Italy)

Abstract - The allochthonous mussel *Musculista senhousia* (Benson in Cantor, 1842) was found in large numbers in the coastal waters of northern and central Adriatic Sea.

Previously successful establishments of *M. senhousia* had been documented only in sheltered bays and lagoons of the Mediterranean. The spreading of this species in open-sea grounds seems thus worth of recording.

Key words: bivalves, *Musculista senhousia*, Adriatic Sea, allochthonous species.

Riassunto - *Musculista senhousia* (Benson in Cantor, 1842) (Bivalvia: Mytilidae) nelle acque costiere del Mare Adriatico (Italia).

Gli Autori riportano il ritrovamento di numerosi esemplari del Mytilidae di origine indo-pacifica *Musculista senhousia* (Benson in Cantor, 1842) nelle acque costiere dell'alto e medio Adriatico. La diffusione della specie in mare aperto non era mai stata documentata in quanto la sua distribuzione in Mediterraneo era nota solo per lagune salmastre e baie. Nell'area investigata, compresa tra Venezia e San Benedetto del Tronto, *M. senhousia* è presente tra i 5 ed i 15 metri di profondità; le massime densità della specie sono state riscontrate al largo di Rimini (65 individui/m^2 ad Agosto; 217 individui/m^2 a Novembre).

Parole chiave: bivalvi, *Musculista senhousia*, Mare Adriatico, specie alloctone.

Introduction

The disturbance caused by massive settlements of allochthonous species within autochthonous assemblages is well-known, acting at various levels (trophic, spatial, etc.) (Ghisotti, 1974a; Zibrowius, 1991; Rossi, 1992). In the past 30 years, the Adriatic Sea, and particularly the northern Adriatic lagoon system, has been affected by invasions of several exotic species (Ghisotti, 1973; 1974b; Cesari & Pellizzato, 1985; Turolla, 1999). The most notorious examples of unintentional introductions being the bivalve *Anadara inaequivalvis* (Bruguière, 1789) and the gastropod *Rapana venosa* (Valenciennes, 1846). Recently, new species, amongst

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which *Anadara demiri* (Piani, 1981) (Morello & Solustri, 2001) and *Musculista senhousia* (Benson in Cantor, 1842) (Bucci, 1994), have made their entrance into this system, representing potential sources of disturbance for benthic communities and for fishing activities targeting infaunal bivalves.

Musculista senhousia is a bivalve of the family Mytilidae. It is native of the Indo-Pacific region (*locus typicus*: Chusan Island, China Sea) and widely distributed from the Sakhalin Peninsula (Russia) to the Philippines and Madagascar, Mauritius, including the Red Sea and the Persian Gulf (Barash & Danin, 1972; Kulikova, 1978; Robba *et al.*, 2002). Its high invasive potential was realised when, in the 1940's, it was first recorded, outside its native areal, off the western coast of the United States (Abbott, 1974; Crooks, 1996). Since then it has been reported in New Zealand (Willan, 1985; 1987) and western Australia (Smith & Brearly, 1987), in the Suez Canal and the south-eastern Mediterranean (Barash & Danin, 1972), in the northwestern Mediterranean (Hoenselaar & Hoenselaar, 1989) and, most recently, in the brackish waters of the northern Adriatic lagoons (Bucci, 1994; Lazzari & Rinaldi, 1994; Mistri, 2002; Russo & Mel, 2002) and in the Gulf of Olbia (Thyrraenian Sea) (Savarino & Turolla from www.cirspe.it). *M. senhousia* mainly inhabits sandy or silty substrata, but has also been found on *Zostera* beds (Kikuchi, 1964; Reusch, 1998), on green algae (Willan, 1987), on mud flats seaward of mangrove forests (Tantanasiriwong, 1979) and on floating structures utilised for mussel culture (Turolla, 1999).

Musculista senhousia is characterized by small size (maximum recorded length: 35 mm; Lazzari & Rinaldi, 1994) and by a thin, semitransparent shell whose colour ranges from yellow to green-brown, fresh specimens exhibiting some irregular, reddish radial bands (Fig. 1).

The reasons for its high invasive capacity and the consequent disturbance to native benthic communities are many. High reproductive potential, with more than one recruitment per year, results in redundant populations whose death can then lead to accumulation of organic matter on the sea-bottom and subsequent anoxic events (Yamamuro *et al.*, 1998). Above all, though, the major disturbing factor is represented by the fact that *M. senhousia* produces a thick weft of byssus. When the species is present in high densities this results in the formation of a "carpet" of byssus which acts as a barrier between the water column and the substratum, seriously limiting gaseous exchange and, consequently, suffocating burrowing organisms (Turolla, 1999; Mistri, 2002).

To date, all successful establishments of *M. senhousia* have been reported for sheltered bays, estuaries and lagoons, such as Lake Nakauma, Japan (Yamamuro *et al.*, 1998), Mission Bay, USA (Crooks, 1996), Sacca di Goro, Italy (Mistri, 2002) and Venice Lagoon, Italy (Russo & Mel, 2002). The spreading of *M. senhousia* in the open-sea coastal grounds of the Adriatic Sea seems, thus, worth recording.

Materials and methods

Specimens of *M. senhousia* were first observed in samples collected in June and September 2001 during the annual surveys carried out in the Maritime Districts of Ancona and San Benedetto del Tronto (central Adriatic Sea) in order to evaluate the stock of the baby-clam, *Chamelea gallina* (Linnaeus, 1758). Overall, these surveys covered an area of about 400 km^2 between the river Cesano and the river Tronto and were limited to depths ranging between 3 and 12 m, for a total of 294 sampling stations. The area was divided into 34, 2 mile-wide, transects per-

Fig. 1 - Specimen of *Musculista senhousia* (L: 20 mm) collected off Marina di Altidona (central Adriatic Sea), depth 5 m, June 2001.
Fig. 1 - Esemplare di *Musculista senhousia* (L: 20 mm) raccolto in corrispondenza di Marina di Altidona (Adriatico centrale) alla profondità di 5 m nel Giugno 2001.

pendicular to the coast. Within each transect, a sample was taken every metre depth between 3 and 12 m. The sampling was carried out by means of an experimental hydraulic dredge with a 6 mm grid (Froglia & Fiorentini, 1988). Each tow covered 40 m^2 of ground. The resulting samples were frozen and subsequently analysed in the laboratory. Additional samples in the San Benedetto Maritime District were collected during monitoring activities in November 2001.

Additional qualitative samples of benthos were collected with a Charcot dredge during 3 experimental fishing campaigns in different localities of the northern Adriatic Sea (Tab. 1, Fig. 2) in May, August and November 2002. During the August and November 2002 campaigns, density estimates of *M. senhousia* were also obtained off Rimini (10 m depth, where it was more abundant than in other sites) by means of a van Veen grab (area 0.1 m^2). The contents of the grab were washed on a 0.5 mm mesh sieve and benthos preserved in 5% formalin solution. All bivalve species were subsequently sorted and identified, and all specimens of *M. senhousia* were measured.

Voucher specimens are deposited in the ISMAR (Section of Ancona) reference malacological collection and in the Natural History Museums of Milano and Genova.

Tab. 1 - Sites of collection and sizes of *Musculista senhousia* specimens collected in the northern and central Adriatic (2001-2002; n. m. = not measureable).
Tab. 1 - Siti di raccolta e range di taglie di *Musculista senhousia* in Adriatico settentrionale e centrale (2001-2002; n. m. = non misurabile).

SITE	POSITION	DEPTH (m)	L min-max (mm)
Porto Garibaldi	44°40.0'N 12°20.9'E	14	13-14
Ravenna	44°23.0'N 12°22.9'E	10	14-20
Rimini	44°05.9'N 12°36.2'E	10	12-23
	44°09.3'N 12°38.7'E	14	18
Pesaro	43°56.8'N 12°51.9'E	10	19-20
	43°59.7'N 12°52.6'E	14	17-22
Cesano	43°45.4'N 13°11.1'E	8	21
	43°45.8'N 13°12.1'E	11	n. m.
Montemarciano	43°40.4'N 13°22.8'E	12	22
Palombina	43°38.4'N 13°25.9'E	10	20
Ancona	43°38.3'N 13°28.1'E	12	23
	43°36.9'N 13°27.9'E	6	1.5-10.6
Sirolo	43°31.1'N 13°38.1'E	10	21; 6 n. m.
	43°31.2'N 13°39.0'E	11	25
Marcelli di Numana	43°29.8'N 13°38.3'E	9	23
	43°30.1'N 13°38.8'E	10	21
Foce Musone	43°28.5'N 13°39.4'E	9	18-25
	43°28.6'N 13°39.9'E	10	17-22
Porto Recanati	43°26.8'N 13°40.6'E	10	19-22
	43°27.0'N 13°41.3'E	11	20
Sud Foce Potenza	43°25.2'N 13°41.0'E	8	20-23
	43°25.2'N 13°41.3'E	9	19-21
	43°25.2'N 13°41.8'E	10	22
	43°25.3'N 13°43.6'E	12	23
Porto Potenza Picena	43°22.3'N 13°42.4'E	9	19-22
	43°22.5'N 13°42.6'E	10	22-23
	43°22.7'N 13°43.6'E	11	19-25
Civitanova Marche	43°20.7'N 13°43.2'E	9	19
	43°19.6'N 13°44.2'E	10	18-22
Sud Foce Chienti	43°17.1'N 13°45.7'E	7	20
	43°17.2'N 13°45.7'E	8	18-22
	43°17.2'N 13°45.9'E	9	22
Lido di Fermo	43°12.3'N 13°48.2'E	6	19
Marina Palmense	43°08.9'N 13°50.1'E	9	7
	43°08.9'N 13°50.3'E	10	5-6
Torre di Palme	43°07.8'N 13°50.8'E	10	2-9
	43°07.9'N 13°50.8'E	11	5
Marina di Altidona	43°06.7'N 13°50.6'E	5	20
	43°06.9'N 13°51.0'E	9	3-4
	43°06.9'N 13°51.3'E	10	3-6
	43°06.8'N 13°51.5'E	11	6

Results and discussion

In the investigated area *M. senhousia* was found to be restricted to the 5-15 m depth range, although the highest numbers were recorded between 9 and 12 m. In particular, its distribution was apparently concentrated off Rimini and south of the Conero promontory (with only 5 specimens between the river Cesano and Ancona and more than 50 between Sirolo and Marina di Altidona; Tab. 1, Fig. 2).

Sampling in the central Adriatic area (from Ancona to Marina di Altidona; Fig. 2), with hydraulic dredges was very intensive, hence the reason for the apparently higher frequency of *M. senhousia* in this area, compared to those recorded in the northern Adriatic.

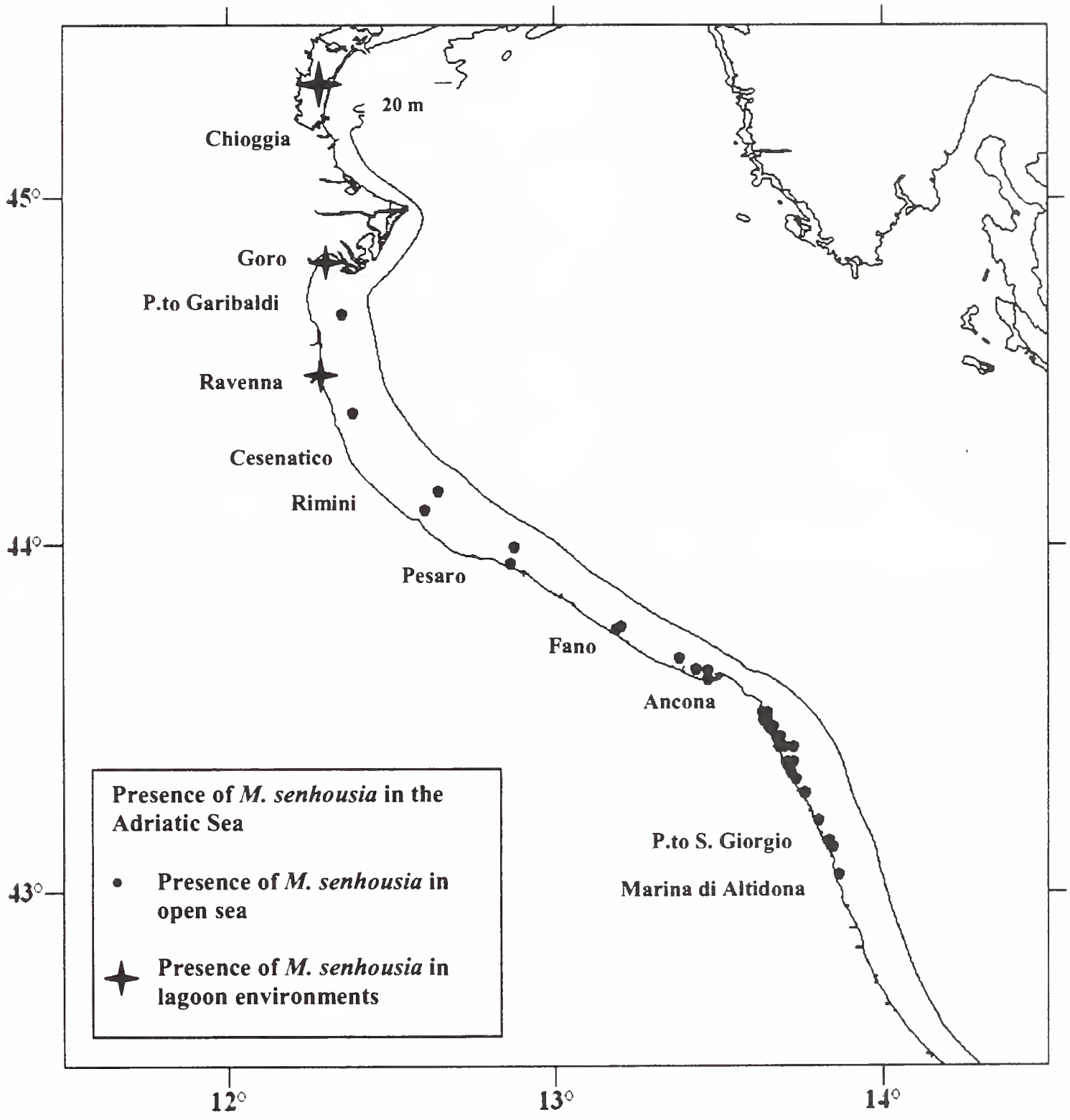

Fig. 2 - Map of sampled area and distribution of *Musculista senhousia* in the Adriatic Sea.
Fig. 2 - Mappa dell'area campionata e distribuzione di *Musculista senhousia* nell'Adriatico.

Marina di Altidona now represents the southernmost limit of the distribution of *M. senhousia* in the Adriatic Sea. Previously, *M. senhousia* was only recorded in the brackish waters of the lagoon systems in the northern Adriatic, on the bottom as well as on floating structures for mussel culture (Turolla, 1999; Mistri, 2002;

Russo & Mel, 2002) but not in the benthos samples collected in recent years in open-sea environments (see Albertelli *et al.*, 1998).

Maximum densities of *M. senhousia* recorded in grab samples obtained off Rimini ranged between 65 and 217 specimens/m^2 in August and November, respectively.

These densities are considerably lower than those recorded in the Adriatic lagoons (up to 1,000 specimens/m^2; (Turolla, 1999) or in California (up to 7,500 specimens/m^2; Crooks, 1996). The higher species richness within marine environments compared to lagoon habitats may have a role in controlling population size.

Musculista senhousia appears to be markedly euryhaline, tolerating salinity values between 2 and 50 psu (Barash & Danin, 1972; Kawahara *et al.*, 1979 in Crooks, 1992). The salinity conditions of the Mediterranean areas in which *M. senhousia* has been reported range from 18 to 29 psu in the Sacca di Goro (Pugnetti *et al.*, 1989) and from 33 to 37 psu off Rimini (ARPA, 2002).

The length-frequency distributions relative to samples collected in open-sea waters off the S. Benedetto del Tronto Maritime District and off Rimini showed the high variability of the dynamics of *Musculista* populations. In fact, the adult cohort present off Marina di Altidona (S. Benedetto del Tronto) in June 2001 (Fig. 3; size range 15-25 mm) went extinct but generated a new cohort observed in November 2001 (Fig. 3; size range 2-9 mm), whereas no recruitment could be detected off Rimini in November 2002, but the cohort observed in August was still florid (Fig. 3; 12-23 mm in August; 18-25 mm in November). On the contrary, Mistri (2002) reported, for the Sacca di Goro, conspicuous recruitment events in late winter-early spring of 1999 and subsequent growth of the recruited cohort which reaches its maximum size in winter (December), coupled with death of the majority of individuals of the "spawner" cohort.

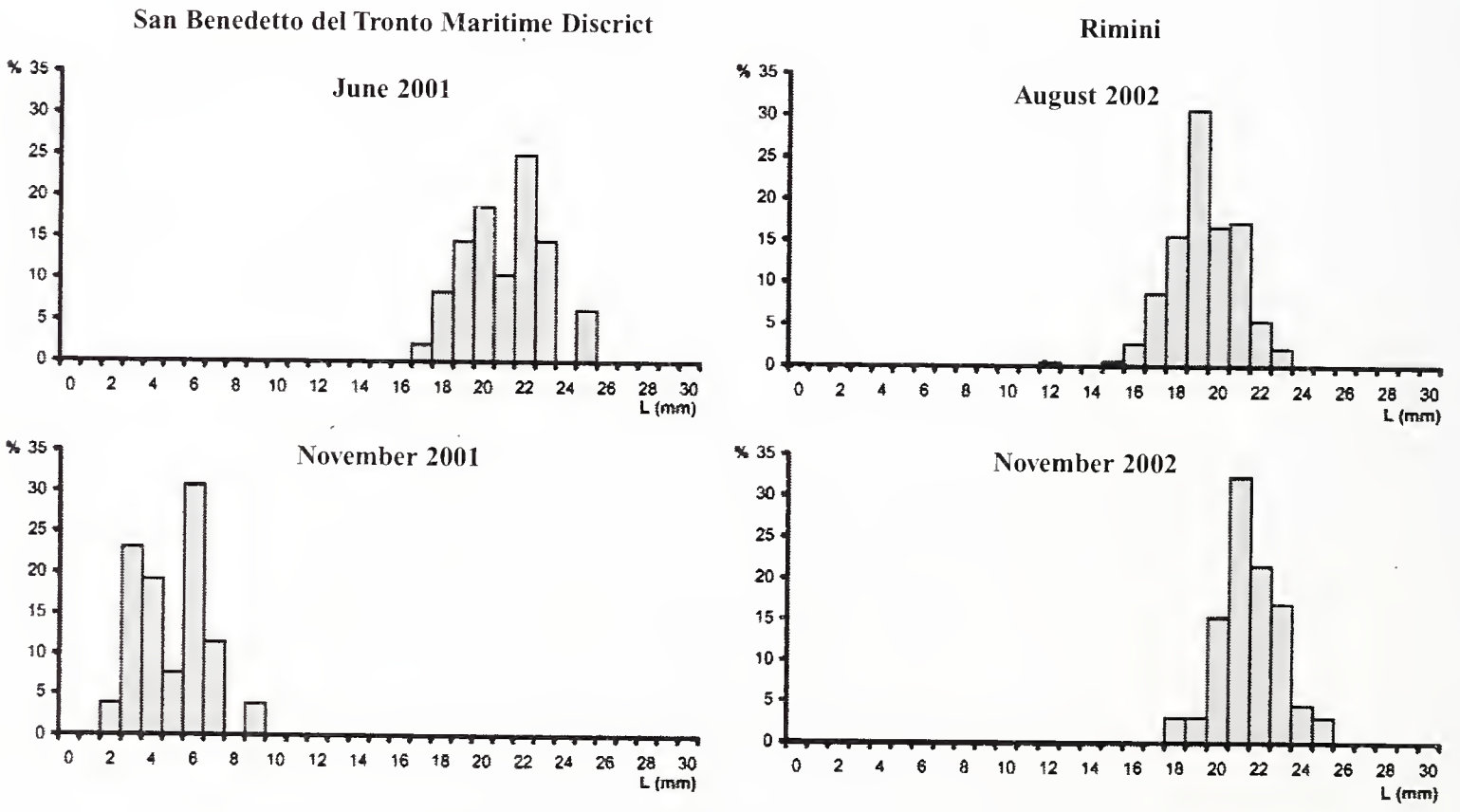

Fig. 3 - Size-frequency distributions of *M. senhousia* populations sampled in the S. Benedetto del Tronto Maritime District in June and November 2001 (left) and off Rimini in August and November 2002 (right).

Fig. 3 - Distribuzioni di frequenza di taglia ottenute per le popolazioni di *M. senhousia* campionate nel Compartimento Marittimo di San Benedetto del Tronto nel Giugno e Novembre 2001 (sinistra) e al largo di Rimini nell'Agosto e Novembre 2002 (destra).

Furthermore, density of *M. senhousia* is very variable in space and time; Lee & Morton (1985 in Robba *et al.*, 2002) report "*M. senhousia* settling at times in large numbers to rapidly dominate a habitat and then with equal rapidity disappearing".

The species of Bivalvia associated with *M. senhousia* in the van Veen grab samples are listed in Tab. 2. It is remarkable that of the 20 species present, three species (*Anadara inaequivalvis, A. demiri, M. senhousia*) are allochthonous, together accounting for 13.5% and 40.9% of the bivalves taxocoene in August 2002 and November 2002, respectively.

Whilst *M. senhousia* has no tolerance to oxygen depletion (Mistri, 2002) the two alien arcids, equipped of more efficient respiratory pigments (De Zwaan *et al.*, 1991), can withstand hypoxic events common in recent years in the coastal waters of the northern Adriatic.

The colonising capacity of the species in open sea environments appears, therefore, to be dictated by different factors. It would, thus, be of utmost importance to gain more information on the year-round population fluctuations of *M. senhousia* in relation to the densities of the other allochthonous and autochthonous bivalves of the benthic community and to the abiotic variables acting within the Adriatic marine environment.

Tab. 2 - Bivalves of grab samples collected off Rimini (44°05.9'N 12°36.2'E; 10 m depth); average densities.
Tab. 2 - Bivalvi presenti nei campioni di benna raccolti al largo di Rimini (44°05.9'N 12°36.2'E; profondità 10 m) con relative densità medie.

Species	August 2002 (n. ind./m^2)	November 2002 (n. ind./m^2)
Nucula nitidosa Winckworth, 1931	233	240
Anadara demiri (Piani, 1981)	10	96
Anadara inaequivalvis (Bruguière, 1789)	30	63
Modiolarca subpicta (Cantraine, 1835)	-	3
Musculista senhousia (Benson in Cantor, 1842)	65	217
Loripes lacteus (Linnaeus, 1758)	-	3
Lucinella divaricata (Linnaeus, 1758)	-	3
Acanthocardia aculeata (Linnaeus, 1758)	3	-
Acanthocardia paucicostata (Sowerby II, 1841)	-	3
Spisula subtruncata (Da Costa, 1778)	14	-
Tellina distorta Poli, 1791	30	2
Tellina nitida Poli, 1791	-	3
Psammobia fervensis (Gmelin, 1791)	-	3
Abra alba (W. Wood, 1802)	14	-
Pharus legumen (Linnaeus, 1758)	7	-
Chamelea gallina (Linnaeus, 1758)	143	130
Dosinia lupinus (Linnaeus, 1758)	10	7
Pitar rudis (Poli, 1795)	3	16
Paphia aurea (Gmelin, 1791)	6	4
Corbula gibba (Olivi, 1792)	203	220

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